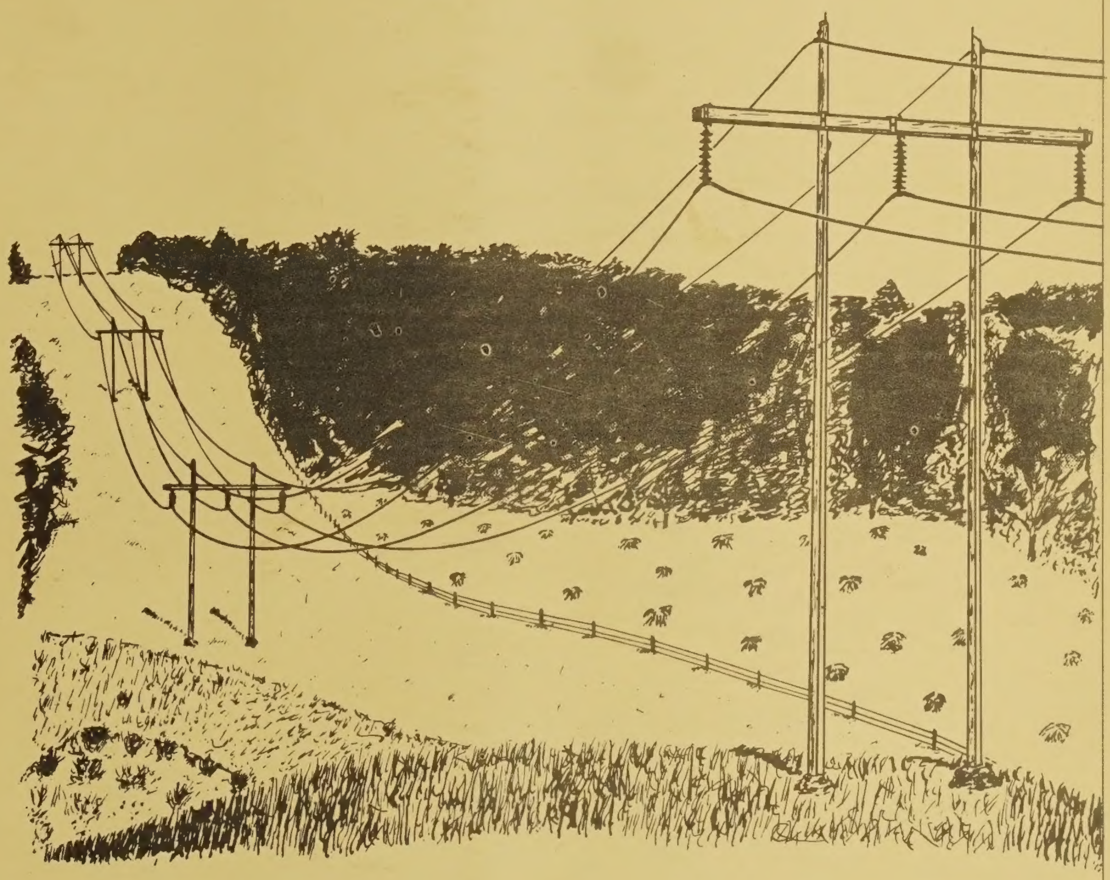
Transmission Line Manual
Physical Design Considerations



UNITED STATES DEPARTMENT OF AGRICULTURE
RURAL ELECTRIFICATION ADMINISTRATION
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SECTION 1

Transmission Line Location and Engineering Survey

The borrowers engineer and right-of-way representative should select a tentative transmission line route, making use of aerial photography, geological survey maps, county soil maps, road maps, post office routes, and airplane strip maps. These maps contain detailed topography and with thumb tacks and thread, an accurate paper location can be made. This location should then be examined on the site by the engineer and right-of-way representative to determine what corrections will be necessary for practicable routing. The line routing should be as straight as practicable since both line angle structures and the consequent increase in line length result in increased construction and operating costs. Deviations from a straight line should be influenced only by topographic features that would make either construction or operation impracticable.

Certain control points should be established from the reconnaissance. Using these control points, a transit line (marked by hub stakes, with tack points for alignment) should be produced between these control points. A right-of-way representative should be in company with or precede this survey party in order to acquaint the property owners with the purpose of the survey, to procure easements, to determine property boundaries crossed, and to maintain good relations with the property owners. The right-of-way representative should avoid making any commitments for individual pole locations before structures are spotted by the engineers on the plan and profile. Another right-of-way representative should begin a check of the records for faulty titles, transfers, joint owners, foreclosed mortgages, etc., against the ownership report by the right-of-way representative who is accompanying the survey. This phase of the work requires the closest kind of coordination between the engineer and the right-of-way representative. Costly details, extravagant misuse of survey time and effort, and misunderstanding on the part of the landowners is to be avoided. There should be a daily check between the engineer and the right-of-way representative.

Immediately after the line is located, as described above, to the satisfaction of both the engineer and the right-of-way representative, a transit and chain survey should begin. This survey will consist of placing stakes at even 100-foot intervals with the station measurements marked on the stakes with suitable crayon. It will also include the placement of intermediate stakes to note the station at property lines, topographic breaks, and for reference points as required. These stakes should be aligned by transit between the hub stakes set on the preliminary survey. This survey party will keep notes showing property lines and topographic features of obstructions that would influence structure spotting. As soon as the final survey is sufficiently advanced a level party should be started taking profile levels along the center line of the survey. Levels should be taken at every 100-foot station and all intermediate points where breaks in the ground surface appear. Wherever

the ground slopes across the line of survey, side shots should be taken a distance of approximately 10 feet beyond the outside conductor position. These elevations to the right and left of the center line should be plotted as short broken lines. These broken lines are referred to as sidehill profiles and are necessary in spotting structures to assure proper ground clearance. Structure spotting should begin as soon as topographic, including level notes, are plotted on the plan and profile sheets.

Prints of these sheets should be furnished the right-of-way representative for checking property lines and for recording easements. One print certified for construction by the manager should be returned to the engineer. Two black and white prints of the plan and profile sheets, with structure spotting complete, should be forwarded to REA for review and approval. One set of the prints will be returned to the engineer approved for construction with recommended changes, if any, noted thereon. The engineer should not wait until all plan and profile sheets of a given line are completed before forwarding to the right-of-way representative and to REA but should send them in groups covering 10 miles or more as they are completed. After the engineer receives an approved print from REA, he is free to release the line for right-of-way clearing, to stake structures and to release the line for construction in accordance with the terms of the construction contract, provided final plans and specifications have been approved.

Occasions may arise where it is necessary to consider rerouting after the final survey is completed, usually from the inability of the right-of-way representative to satisfy the demands of a property owner. In such instances, it is the responsibility of the engineer to analyze the problem on the basis of cost. The engineer should make a preliminary survey to determine the length and difficulties of rerouting and determine the over-all added cost of relocating. The right-of-way representative should furnish the engineer an estimate of the cost of the demands of the property owner and an estimate of court costs. The engineer will then recommend to the system's board of directors, through the manager, the most reasonable course to pursue. The board of directors will then resolve to pay the property owner, condemn the property, or instruct the engineer to relocate.

The procedure outlined above should insure the building of a line quickly and least expensively. It is essential that this procedure be followed closely and that there be complete cooperation between the engineer and the right-of-way representative.

Vertical Clearances for Transmission Lines

Most transmission lines have many spans which are of such length that the maximum increased clearance above the minimum clearances specified by the NESC must be provided. Also, because of the limits of accuracy in the preparation of plan and profile drawings, and in the sagging of conductors, it is not considered desirable for designs to allow for only the bare minimum clearances specified by the NESC. With these factors in mind, and to establish uniform clearances for sag templates used for spotting transmission line structures, the clearances shown in the following table have been developed for use in spotting transmission structures on plan and profile sheets with 120° final sag curves. These clearances are somewhat in excess of the minimum clearances prescribed by the NESC, and will in all cases fall within the prescribed limits of the Code. These clearances assume that the maximum conductor design tension does not exceed 50 percent of the ultimate strength, as increased clearances are usually required with higher design tensions. Design tensions in excess of 50 percent of the ultimate strength should not be used unless specifically approved by REA. The clearances are satisfactory for use with the 120° final curves for most sizes and types of conductors usually used on transmission lines. For No. 2 ACSR, 7/1 stranding, and for smaller ACSR sizes additional clearances may be required. Additional clearances may also be required for Copperweld-copper conductors smaller than No. 4. Small conductor sizes on transmission lines are generally not desirable. State and Railroad Codes should be consulted and clearances greater than those shown should be used if required.

The template for spotting structures should be cut to allow one foot greater clearance than the recommended ground clearance in order to provide flexibility for minor shifts in structure location, if necessary, when structures are staked. If it is necessary to change the location of any structures when the line is staked, the plan and profile must be corrected accordingly.

It is recommended that the crossing clearances shown in the table be maintained regardless of the location of the point of crossing relative to the center of the span. Only in exceptionally difficult cases should the clearances be reduced when the point of crossing is near the supporting structure.

Recommended Minimum Vertical Clearances for Spotting Structures on Plan or Profile Sheets *1 *2 (120° Final Sag, Maximum Conductor Design Tension 50% of Ultimate Strength)

	33kv	44kv	69kv	115kv	161kv
Over railroads	32	32	33	35	36
Over streets and highways	25	25	26	28	29
Over communication lines	8	8	9	11	12
Over supply lines up to 50,000 volts	6	6	7	9	9
Over space accessible to pedestrians only	19	19	20	22	24
Over cultivated fields *3	20	20	21	23	25
Along roads in rural districts	22	22	23	25	27

Notes: *1 Sag templates should be cut to allow one foot greater clearance than shown above.

*2 Additional clearance may be required for No. 2-7/1 stranding, and smaller ACSR sizes, and for Copperweld-copper sizes smaller than No. 4 in medium and light loading zones.

*3 The NESC does not specify the clearances that should be maintained across cultivated fields, but there are relatively few places that could be strictly considered as being "accessible to pedestrians only." Ordinarily, therefore, when lines are routed across open country, templates should be based on the clearances recommended over cultivated fields as shown in the table. It will be noted that these clearances are one foot greater than the clearances recommended over spaces accessible to pedestrians only, and should be sufficient in most cases. Local conditions may call for deviations from these recommended minimum clearances. Where special conditions merit increased clearances, the engineer should submit detailed justification to REA for consideration prior to the preparation of plans and specifications.

SECTION 3

Strength and Span Limitations for Transmission Line Conductors

Transmission lines are relatively more costly than are distribution lines and requirements for the continuity of service are much greater. Therefore, these lines are usually engineered with the use of plan and profile drawings, and it is necessary that special care and attention be given to conductor sags and tensions.

For transmission line conductors, it is generally recommended that the design tension under conditions of maximum design load not exceed 50 percent of the ultimate strength of the conductor for the ruling span selected. Unloaded design tensions should in no case exceed the tensions recommended by the conductor manufacturers. Loaded design tensions in excess of 50 percent of the ultimate tension should not be used unless specifically approved by REA.

One of the most important single factors in the design of a transmission line is the selection of the ruling span. Since structures must be spotted on the plan and profile by means of a sag template, which is based on the ruling span, the ruling span must be selected before the template can be made. The "ruling span" may be considered as an assumed "design span" that assures the best average tension throughout a line of non-uniform span lengths. It must be remembered that the actual tension, under both loaded and unloaded conditions may be greater or less than the ruling span tension, depending upon span length, ground elevation, stringing temperatures and loading conditions, etc. A customary rule is to estimate a ruling span, which will approximately equal the average span, plus two-thirds of the difference between the maximum span and the average span. Generally, it is not essential that a ruling span computed by this rule after structures are spotted be equal to the estimated ruling span on which the sag template is based. Usually the difference will not be enough to require changing the ruling span, but if there should be more than approximately ten percent difference it will be advisable to make a check with another ruling span, to see whether this difference will have any significant effect on spotting. As long as the estimated ruling span results in economical structure spotting without excessive tensions, it will be satisfactory. Under some circumstances, as described below, where the maximum unloaded tension is the controlling tension, the rule should not be applied.

With due consideration to necessary ground clearance, type of configuration, type of terrain, and loading assumption, a ruling span for design should be chosen that will, if possible, be applicable throughout the length of the line. Spans considerably in excess of the ruling span may be taken without the necessity for costly dead-end structures, and it is common practice to permit occasional spans up to double the average span without dead-ends. Dead-ending for the purpose of changing ruling spans is costly and not necessary, except where extremely long spans are encountered. For example, if a line of No. 1/0 ACSR is

designed for medium loading with a maximum loaded tension of 2,140 pounds (50 percent of the ultimate strength), in a 600-foot ruling span, the stringing tension at 60° is 920 pounds. A 1000-foot span strung at this tension at 60° will develop under full load at 15°, a tension of approximately 2,575 pounds or 60 percent of the ultimate strength. The flexibility of the supporting structures would reduce this tension even lower, and there would be no purpose in dead-ending the 1000-foot span.

Another example would be with No. 1-7 strand H.D. copper conductor, designed for heavy loading with a maximum loaded tension of 1,902 pounds in a 400-foot ruling span. The initial stringing tension at 60° is 533 pounds. If an 800-foot span is strung in at 60° to a tension of 533 pounds, the tension will rise to approximately 2,235 pounds or 58.6 percent of the ultimate strength, under full load at 0°. No attempt will be made here to set the length of ruling spans that should be used under various circumstances. Where the maximum allowable tension under loading conditions assumed is the controlling design tension, it may be generally stated that ruling spans from 100 to 300 feet in excess of the normal level ground span are most satisfactory. As a rule the permissible increase in length of ruling span over the level ground span is greater as the level ground span becomes longer and as the terrain becomes rougher. The longest ruling span practicable that does not unduly shorten the average span length, and thereby increase the over-all cost of the line should be used.

Long ruling spans under the above design conditions have advantages over shorter ruling spans in that: unloaded tensions are reduced, thereby reducing any tendency for the conductors to vibrate; the possibility of uplift in grading the line from low to higher elevations is reduced; and longer spans can be taken without the necessity for dead-ending.

Where the maximum allowable tension at prescribed temperatures, without loading on the conductor, is the controlling design tension, and the maximum loaded tension for the ruling span is substantially below 50 percent of the ultimate strength, it may generally be stated that a ruling span of approximately the same length as the normal level ground span should be used. Where this condition governs, it is quite possible that increasing the ruling span would have effects opposite to those desired as described above. The maximum allowable unloaded tension is the controlling tension more frequently in light and medium loading areas than in heavy loading areas.

All of the above discussion assumes that conductors will be properly sagged in at the proper stringing tension for the ruling span selected. In stringing conductors, sags should always be checked in spans as nearly equal to the ruling spans as possible.

No effort will be made to illustrate the methods of computing conductor sags and tensions. Several satisfactory methods have been developed and instructions are available in various textbooks and in publications of the conductor manufacturers.

Structural Stress Limitations for Wood Pole Transmission Lines

The structural stress limitations set forth in this section are recommended for transmission lines using REA standard wood pole construction. No attempt has been made to set strength limitations at the minimum values allowed by the NESC, and the recommended values are in no case below the requirements of the NESC for grade "B" construction.

Wood poles: With the assumed loads, as prescribed by the NESC, the maximum fiber stress for poles of tangent structures should not exceed 25 percent of the ultimate strength at the ground line, or at the point of guy attachment when guys are installed. Guys should be placed on all line angles greater than 1^{o}.

A convenient method for determining the maximum allowable horizontal spans for various heights and classes of poles is outlined in Section 5 which covers the selection of the proper height and class of poles for transmission lines.

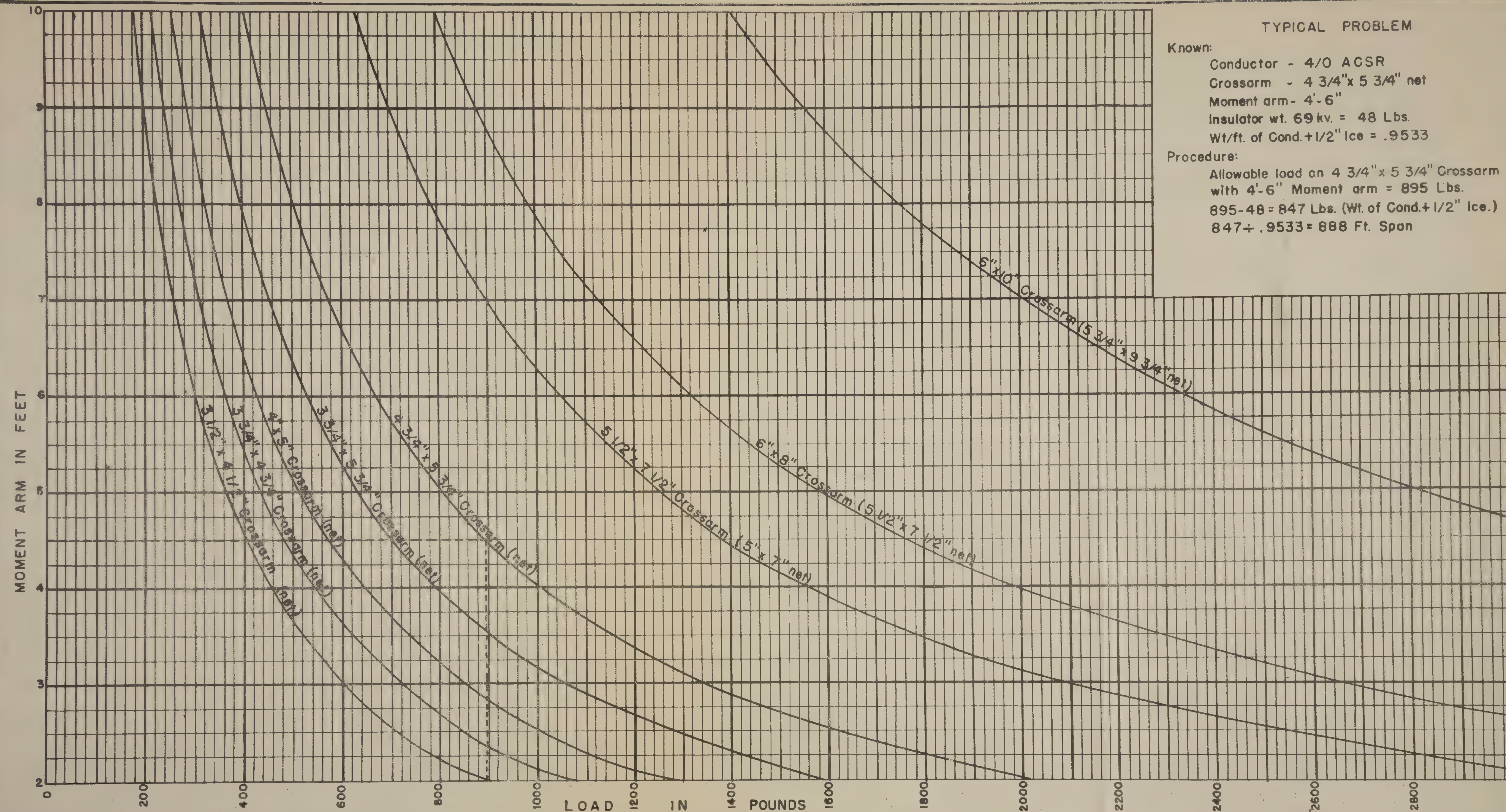
Crossarms: The maximum fiber stress in crossarms, computed by taking moments about the through-bolt, without considering the strength of the crossarm brace, should not exceed 25 percent of the ultimate strength under the weight of insulators and conductors supported by the structure. The vertical weight of conductors supported by a given structure is the weight of the vertical span supported by the structure under the assumed ice load at 32^{o}. The "vertical span" is the horizontal distance between the low points of sag in spans adjacent to the structure. Drawing TM-8, Crossarm Loading Chart, offers a convenient method for determining the maximum allowable vertical spans for various sizes of Douglas Fir crossarms. A typical problem is illustrated on the drawing. The strength of the crossarm brace may be considered as being available to support any unusual load, such as the weight of a lineman, or any unexpectedly heavy or unbalanced ice loads.

Anchors: To insure proper installation and full strength, it is generally recommended that log anchors only be used for transmission lines, except where rock anchors may be installed or where difficult soil conditions exist. Only two sizes of anchor logs, 8" x 5'-0" and 8" x 8'-0" are necessary for guying any wood pole transmission line using conductors with design tensions not exceeding approximately 5,000 pounds. These logs, using one or two anchor rods as shown on drawings TA-1-5 and TA-1-8, may be used in combination as required to provide the necessary strength. The maximum working loads for these anchors of 8,000 pounds and 16,000 pounds, respectively, have been computed as 50 percent of the ultimate holding power in average soil. Maximum working loads shown for anchor rods, though less than 50 percent of the breaking strength, have been coordinated with the strength of the logs.

Guys: Three-eighth-inch high strength steel strand is adaptable to all guying problems using the log anchors referred to above, and it is generally recommended for use on all transmission lines. It is always recommended that only one size and type of guy strand be used on any one transmission line. If the line has a steel overhead ground wire (usually 3/8-inch high strength strand), the same strand should be used for the guys. The guy strand should be used in combinations of single and double guys with five- and eight-foot anchor logs, as shown on drawing TG-1, 2, 3, and 4 to provide the required strength. For each line, a drawing should be prepared showing the arrangement of guys for each type of structure to be used. Drawing TM-6 is a specimen of such a drawing. It will be noted that the guys required for various line angles are based on assumed level ground spans. Since actual spans will vary, the guying requirements shown will not be exact for all conditions. The guying requirements for the various line angles will be sufficiently accurate, however, so that a minimum of actual computation will be required of the engineer spotting structures on the plan and profile. The drawing will also greatly facilitate the review of the plan and profile, and construction of the line. It will be noted that the specimen drawing shows the points of attachment to the pole, slope of guys, type of structure, and guys required for various line angles. For side guys on tangent structures under transverse loading assumptions as prescribed by the NESC, fifth edition, it is recommended that the maximum allowable tension in guy strands not exceed 25 percent of the ultimate strength. At angles in the line, it is recommended that the transverse wind load be multiplied by 2 and that the maximum allowable tension in the guy under the transverse-wind load thus computed, combined with maximum conductor tension, not exceed 50 percent of the ultimate strength. At dead-ends, it is recommended that the maximum allowable tension in the guy not exceed 50 percent of the ultimate strength at conductor design tension.

Insulators: It is recommended that the maximum tension on standard 5 3/4" x 10" suspension insulators not exceed 5,000 pounds. For insulator pins and post-type insulators, it is recommended that the maximum transverse load, whether from wind load alone on tangent structures, or from a combination of wind load and conductor tension on angle structures, be limited to 500 pounds per insulator. This limitation will prevent excessive stresses on insulators, insulator pins, the wood of crossarms and poles, and hardware. Structures with double insulator support may be used where the transverse load is between 500 and 1,000 pounds.

When the above limitations are used with standard REA wood pole structures, the designs which result will be in keeping with the best recognized transmission line engineering practices. To facilitate the spotting of structures on the plan and profile sheets, and review of plans and specifications, these structural stress limitations should be converted to span length limitations as shown in paragraph 6 of Form DS-212R, Transmission Line Design Data Summary.



TYPICAL PROBLEM

Known:

Conductor - 4/0 ACSR
Crossarm - 4 3/4" x 5 3/4" net
Moment arm - 4'-6"
Insulator wt. 69 kv. = 48 Lbs.
Wt/ft. of Cond. + 1/2" Ice = .9533

Procedure:

Allowable load on 4 3/4" x 5 3/4" Crossarm with 4'-6" Moment arm = 895 Lbs.
895 - 48 = 847 Lbs. (Wt. of Cond. + 1/2" Ice.)
847 ÷ .9533 = 888 Ft. Span

	INSULATOR WEIGHTS	
	LINE KV.	AVG. Wt. Lbs.
suspension	46	36
	69	48
	115	84
	154	132
TP-I	34.5	25
	44	30

COPPER CONDUCTORS					
CONDUCTOR SIZE	WT. +1/4" ICE	WT. +1/2" ICE	CONDUCTOR SIZE	WT. +1/4" ICE	WT. +1/2" ICE
4- Solid	.2676	.5643	250 cm. 12 str.	1.0363	1.456
2- 3 str.	.3801	.7128	300 cm. 19 str.	1.200	1.628
1 - 7 str.	.4381	.7732	350 cm. 19 str.	1.370	1.814
1/0 - 7 str.	.5178	.8654	400 cm. 19 str.	1.538	1.997
2/0 - 7 str.	.6173	.9792	500 cm. 19 str.	1.874	2.359
4/0 - 12 str.	.9026	1.307	500 cm. 37 str.	1.874	2.360
4/0 - 19 str.	.8952	1.292			

ACSR CONDUCTORS			STEEL CABLES			COPPERWELD		
CONDUCTOR SIZE	WT. +1/4" ICE	WT. +1/2" ICE	CABLE SIZE	WT. +1/4" ICE	WT. +1/2" ICE	CABLE SIZE	WT. +1/4" ICE	WT. +1/2" ICE
2 - 6/1	.2676	.5992	5/16	.380	.710	3/8	.5213	.8742
1/0	.3471	.7042	3/8	.463	.807	7/16	.6207	.9885
2/0	.4005	.7727	7/16	.612	.981	1/2	.7438	1.128
4/0	.5449	.9533	1/2	.748	1.136	2 F	.3963	.7252
266,800	.6430	1.076				1 F	.4662	.8069
397,500	.8677	1.344				1/0 F	.5524	.9062
3/0	.4655	.8548						

CROSSARM LOADING CHART

Maximum allowable vertical loads on various sizes of Douglas Fir crossarms and moment arms under any condition of loadings. Fibre Stress = 1850 Lbs/Sq. In. (25% Ultimate for D.F.)

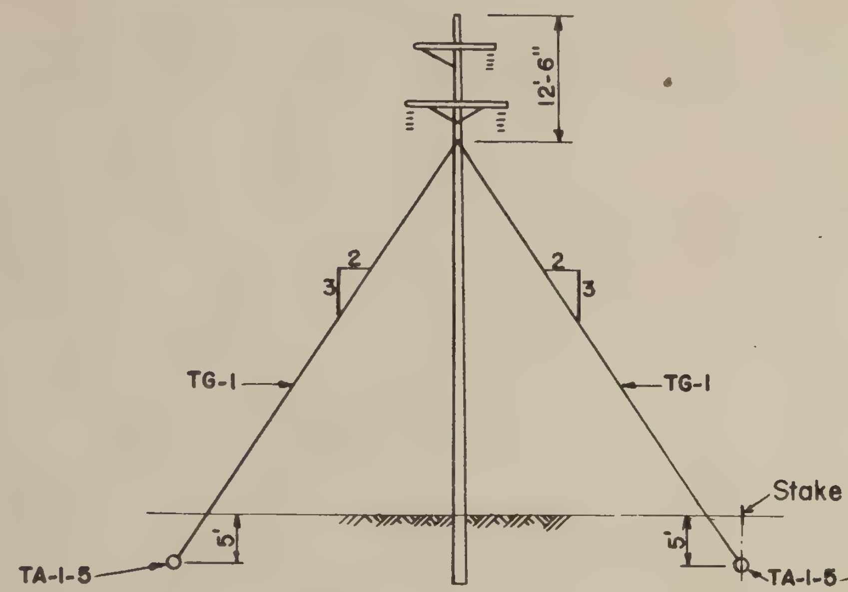
Scale:

Date:

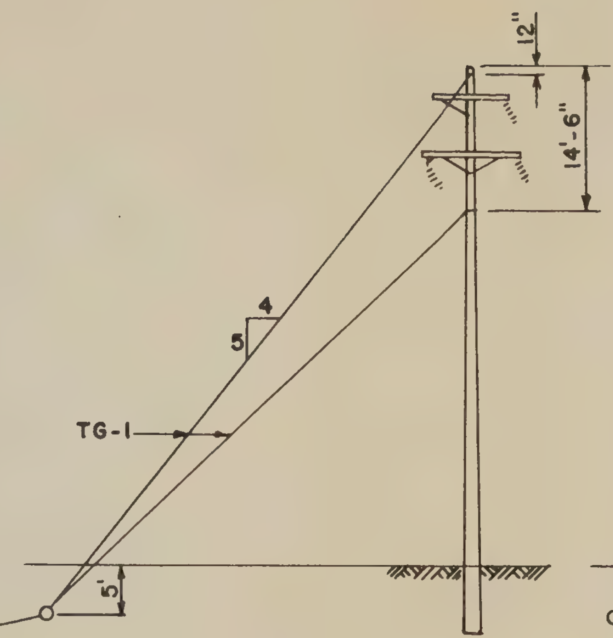
TM-8

911530 O—50 (Face p. 8) No. 1

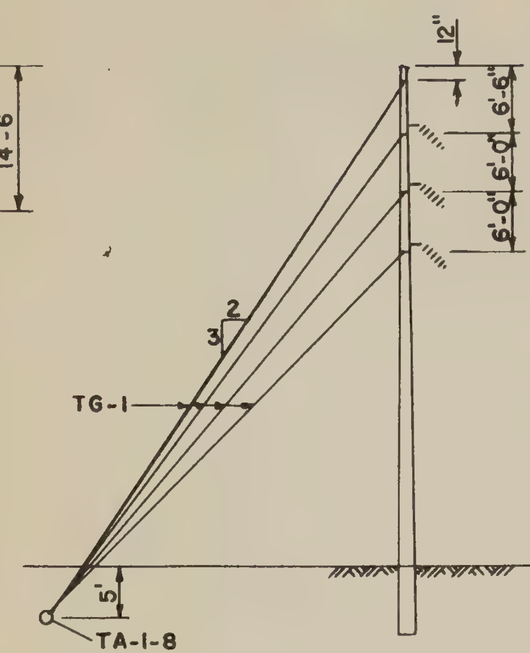
CONDUCTOR: Design Tension- 3337 Lbs., Size - 3/0
Material - ACSR, Stranding - 6/1
GROUND WIRE: Design Tension - 3700 Lbs., Size - 3/8"
Material-H.S. Steel, Stranding - 7
LOADING: 1/2" Ice, 4 Lb. Wind at 0° F.
RULING SPAN: 600'   STANDARD POLE: 50' Class 2
MINIMUM GROUND CLEARANCE: 21'
VOLTAGE: 69 KV.



TYPE TS-1
TYPE TS-2
Side Guys



TYPE TS-1
TYPE TS-1B
Bisector Guys

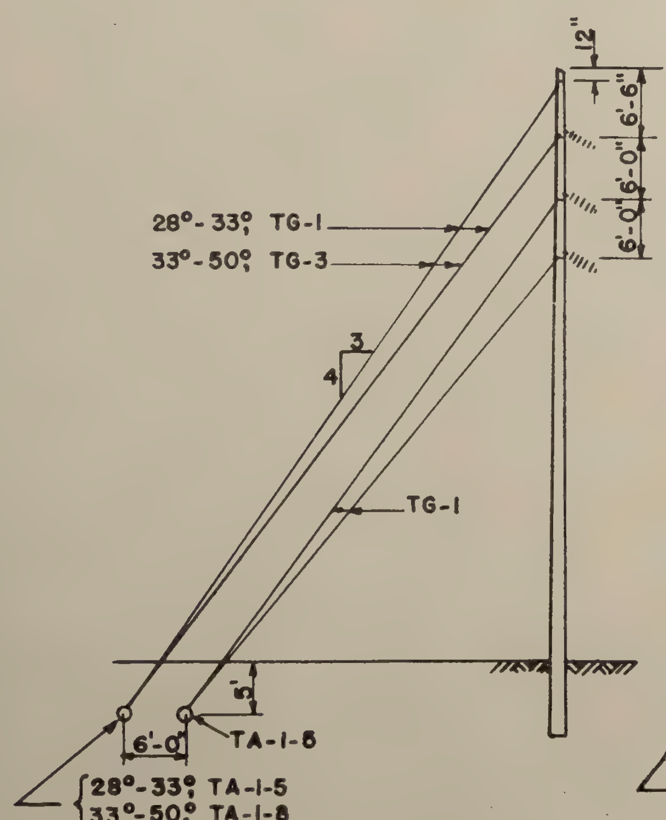


TYPE TS-3G
Bisector Guys

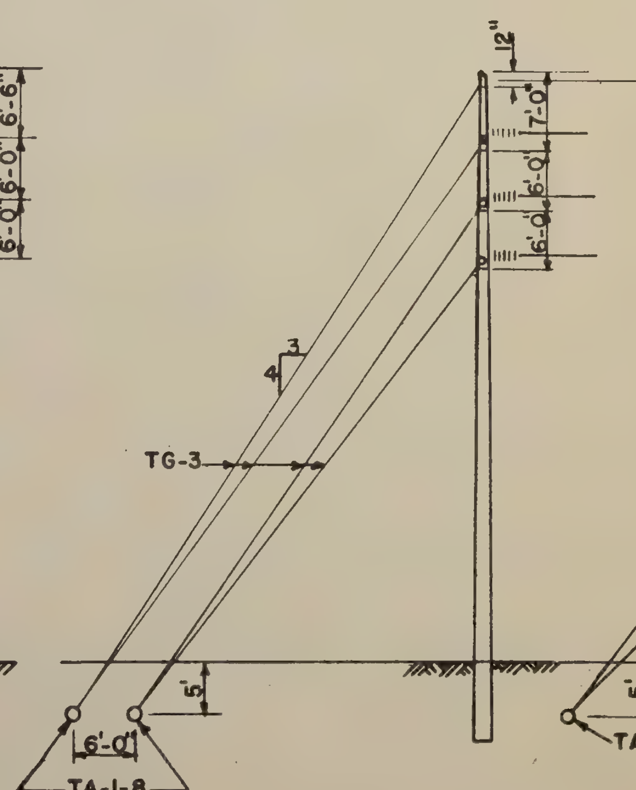
Normal Level Ground Span	470'
Maximum Horizontal Span (TS-1 horizontal separation)	1000'
Maximum Sum of Adjacent Spans Without Guys	950'
Maximum Sum of Adjacent Spans - Side Guyed	1850'
Maximum Vertical Span - Single Arm	990'
Maximum Vertical Span - Double Arm	1980'

GUYS BASED ON 500' SPAN

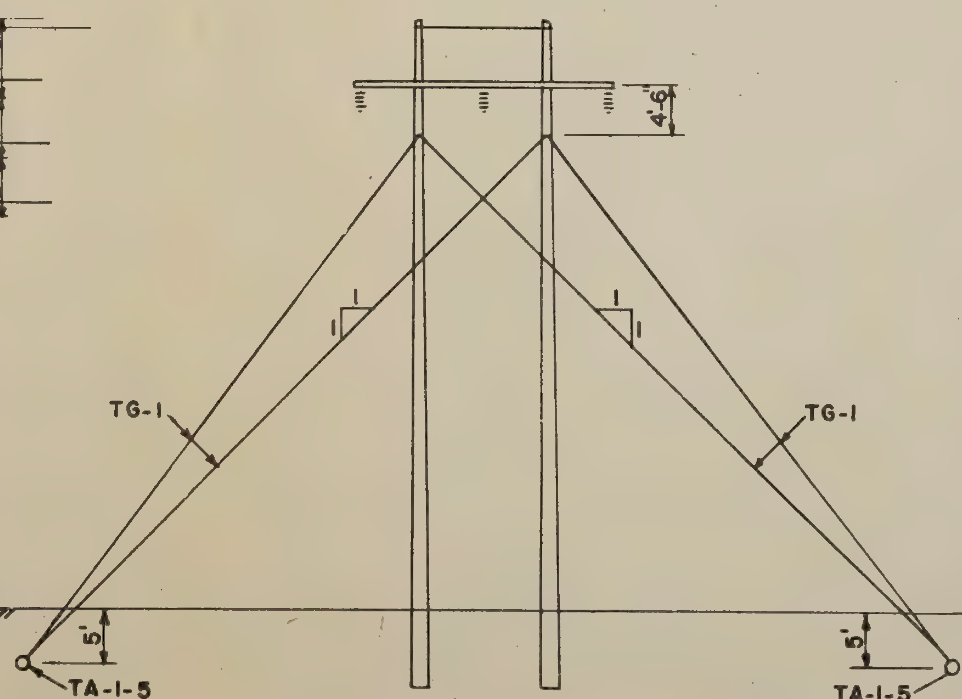
TYPE STRUCTURE	LINE ANGLE	GUYS REQUIRED	LOGS REQUIRED	GUY LOCATION
TS-1	0°	1- TG-1	1- TA-1-5	Each Side
TH-1	0°	2- TG-1	1- TA-1-5	Each Side
TS-1	0°- 4°	1- TG-1	1- TA-1-5	Bisector
TS-2	0°- 4°	1- TG-1	1- TA-1-5	Bisector
TS-1B	4°-12°	2- TG-1	1- TA-1-5	Bisector
TS-3G	12°-28°	4- TG-1	1- TA-1-8	Bisector
TS-4G	28°-33°	4- TG-1	2- TA-1-5	Bisector
TS-4G	33°-50°	2- TG-1 2- TG-3	1- TA-1-5 1- TA-1-8	Bisector
TS-5G	50°- Up	4- TG-3	2- TA-1-8	Head & Back



TYPE TS-4G
Bisector Guys



TYPE TS-5G
Head and Back Guys



TYPE TH-1
Side Guys

SPECIMEN

ARRANGEMENT OF GUYS AND DESIGN SUMMARY SHEET
FOR SUSPENSION TYPE STRUCTURES

Scale: None		Date:
		TM-6

911530 O—50 (Face p. 8) No. 2

SECTION 5

Selection of the Proper Height and Class of Poles for Transmission Lines

All sections of transmission lines having the same loading should be designed for the use of only one class of pole unless economic justification for the use of more than one class of pole can be shown. When transmission line structures are located by means of a plan and profile, it is relatively simple to design a line having uniform configuration and conductor size with a single class of pole. Lines utilizing only one class of pole have the following advantages over lines using several classes of poles:

1. Usually orders for poles must be placed before plan and profile sheets are prepared and before exact quantities of materials needed are known. Estimates of pole quantities, procurement of poles, and schedules for shipping and shipping points are greatly simplified. If more than one class of pole is to be used, it is extremely difficult to estimate with any degree of accuracy the number of poles of various heights and classes that will be needed. The difficulty is aggravated because there are usually several shipping points to which poles must be delivered.

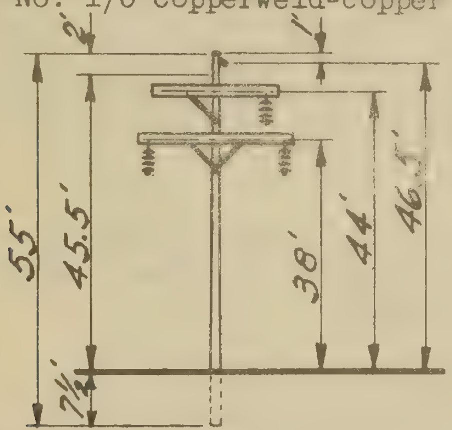
2. Construction of the line is simplified because there is no necessity for segregating poles according to class, either in storage or when poles are distributed.

On any given line, there may be a few occasions where spans must be so short that a pole of lower class than the basic pole would have sufficient strength, and a very few occasions where spans must be so long that the basic class pole would have insufficient strength. Skillful spotting of structures on the plan and profile, however, will almost always result in span lengths that are within the strength limitations of the basic class of pole in over 90 percent of the cases. The economic advantage of using lower or higher classes of poles should be carefully investigated in order that no sacrifice in design will result.

Maximum flexibility in span lengths within the range of strength for a single class of pole can normally be obtained when the allowable horizontal span (one-half the sum of adjacent spans) for the basic class of pole is approximately 10 percent greater than the level ground span. It is not always possible to obtain this approximate relation, but when the difference between the level ground span and the maximum allowable horizontal span for a given class of pole is very small, it is generally more economical to use the next higher class of pole for the line. This will depend upon local conditions and type of terrain.

The Wood Pole Loading Chart, drawing TM-18, offers a convenient method of quickly determining the maximum horizontal spans for all classes and heights of poles with any configuration of conductors. To use the chart, the load must be computed which, when applied 2 feet from the top of the pole, will balance the moment of wind loads on conductors for an arbitrarily selected span and pole height. A line drawn through the point corresponding to the selected span length and the load thus computed and through the origin (point 0) will intersect the horizontal lines representing the maximum allowable load on various classes and heights of poles. The points of intersection determine the maximum allowable horizontal spans (one-half of the sum of adjacent spans for grade B construction). Guide points for various sizes of conductors, for pole-top, pin-type construction only, have been plotted on the chart for convenience. For any other configuration, the point to be plotted must be computed as described below. (The chart should not be used for light loading computations.)

The following example illustrates how the chart would be used with structure TS-1, assuming heavy loading, 3/8"-high strength steel ground wire, No. 1/0 Copperweld-copper conductor, and 55-foot poles:



4# wind on ground wire = .453#/ft. (5th Ed.NESC)

4# wind on conductor = .4627#/ft. (5th Ed.NESC)

Consider conductor load applied to pole at point of crossarm attachment. Assume a 500-foot horizontal span.

Moments about ground line:

Overhead ground wire = (.453) (500) (46.5) =	10,532 ft. lbs.
Conductor on top crossarm = (.4627) (500) (44) =	10,179 ft. lbs.
Conductors on bottom crossarm = (.4627) (500) (38) (2) =	17,583 ft. lbs.
Total moment about ground line =	38,294 ft. lbs.

Load applied 2 feet from top of pole which will balance the moment of wind loads on the conductors $= \frac{38,294}{45.5} = 842$ pounds

When the point on the chart corresponding to 842 pounds and a 500-foot span is plotted, and a line is drawn through this point and the point of origin, the maximum allowable horizontal span for all classes and heights of poles may be read directly. Thus, it will be seen that the maximum horizontal span for a 55-foot class 1 pole is 605 feet; for a 55-foot class 2 pole is 490 feet; and for a 50-foot class 3 pole is 400 feet.

If the line is 69 kv and the sag template is cut for 21 feet of ground clearance with the 120° final curve, the allowable sag on level ground with 55-foot poles is 14.5 feet. With a 600-foot ruling span, 14.5 feet of sag will allow a span of approximately 555 feet. Since the class 2 pole will allow a span of only 490 feet, it would not carry the normal level ground span, and class 1 poles would be required if 55-foot basic poles were used. With 50-foot poles, however, the allowable sag is 9.5 feet, which will allow a level ground span of 455 feet with a 500-foot ruling span. Since the class 3 pole will allow a span of only 400 feet, it would not carry the normal level ground span, and class 2 poles would be required if 50-foot basic poles were used. Thus, the basic pole height and class should be selected on the basis of a comparison of the costs of construction using 55-foot class 1 poles, and 50-foot class 2 poles.

EXAMPLE:

Knowing (1) class of pole, (2) Size and type of conductor, (3) loading district, (4) standard length of pole - it is possible to determine the maximum horizontal span using the chart shown. An example of its use is shown.

Class 3 pole, 2/0 ACSR, Heavy loading, and 40' pole height. From chart the allowable span is 467 feet.

If the conductor is not given or a definite span is to be checked the procedure is as shown below. Compute the resultant transverse load, L_R applied 2 feet from top of pole necessary to balance moment of conductor loads. Plot this load under correct loading on chart. Connect this point and the 0 point and then read chart as before.

An example of the latter case:
40' pole, 600' span, 2/0 ACSR, Heavy Loading. This loading gives .4823#/ft. transverse load = W_H. Substitution in the formulas below gives:

H = 40', d = 6', A = 600 x .4823 = 290

B = 600 x .4823 x 2 = 579

Y_R = 32', Y_B = 32', Y_A = 35', L_R = ? , G = ?

M_A = 600 x .4823 x 35 = 10,100

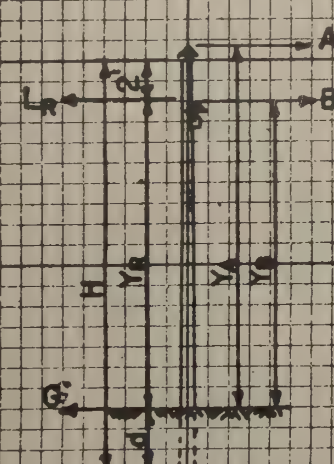
M_B = 600 x .4823 x 32 x 2 = 18,500

M_R = 28,600

L_R = 28,600 / 32 = 893# (Plot on 600' line)

Σ H = 0, G = 0,

Maximum horizontal span, 40' cl. 3 = 467'



H = Pole height

d = Setting depth

A = Transverse load on 1 cond.

B = Transverse load on 2 cond.

L_R = Force necessary to balance moment of conductor loads. L_R is applied 2' from top of pole.

Y_R, Y_A, Y_B, are the lever arms to their respective forces, measured from the ground line.

G = Force necessary to balance loads in a vertical plane.

Taking moments about the ground line to determine L_R.

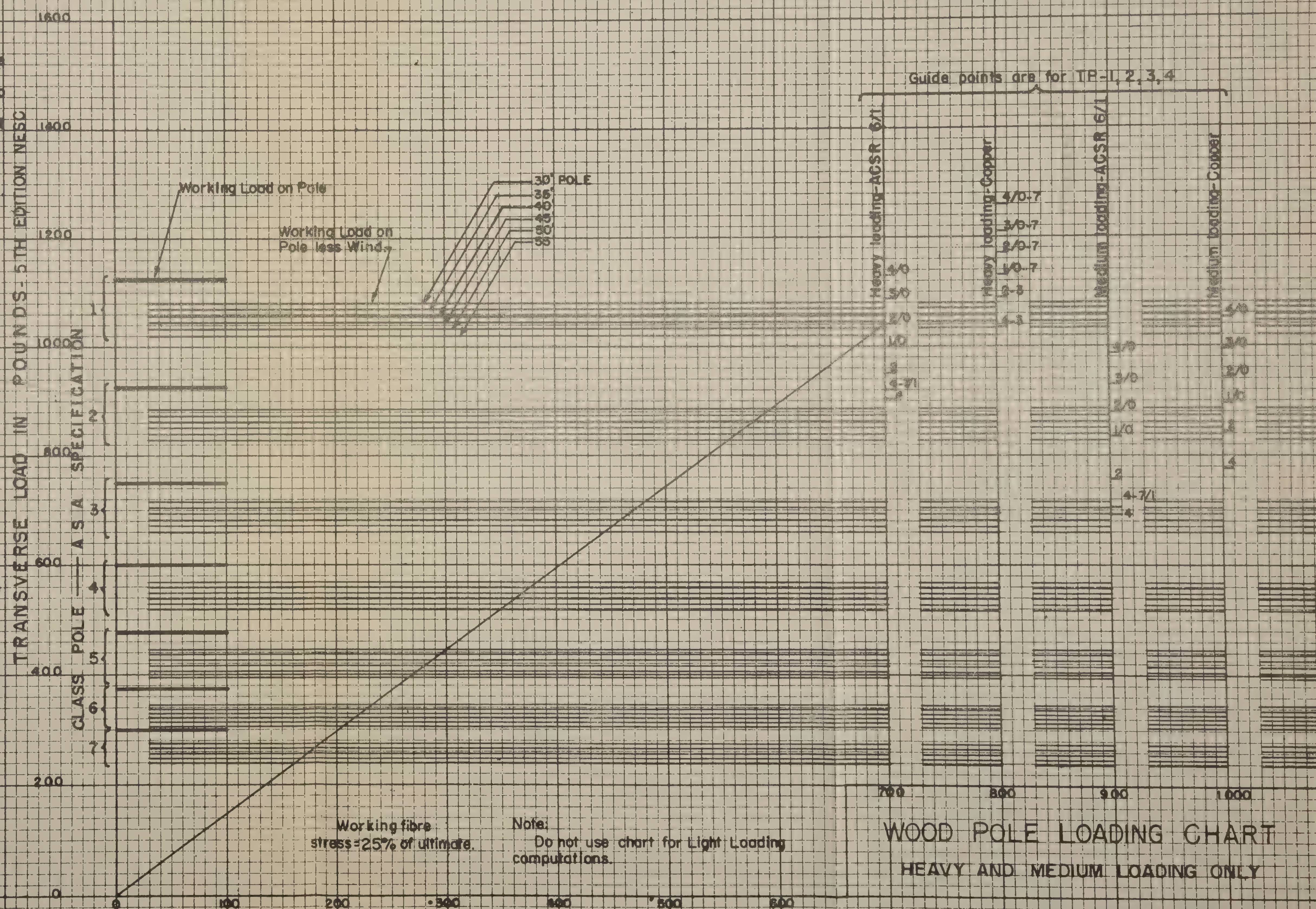
$M_A = A \times Y_A = \text{Span} \times W_H \times 1 \times Y_A$

$M_B = B \times Y_B = \text{Span} \times W_H \times 2 \times Y_B$

$M_R = L_R \times Y_R$

$\Sigma M = 0$

$\therefore L_R = \frac{M_A + M_B}{Y_R}$



WOOD POLE LOADING CHART

HEAVY AND MEDIUM LOADING ONLY

TM-18

SECTION 6

Overhead Ground Wire Sags and Tensions

The primary function of overhead ground wires is to protect transmission lines from lightning surges. To avoid unnecessarily high mechanical stresses in the ground wire, supporting structures and guys, the ground wire should not be strung with any more tension than is necessary to prevent midspan flashovers from the conductor to the ground wire. There will be little danger of such flashovers on lines using standard REA wood pole transmission structures if the sag of the overhead ground wire is approximately 80 percent of the sag of the conductor. It is, therefore, recommended that the loaded design tension of overhead ground wires shall not exceed the amount necessary to allow the sag of the ground wire to be 80 percent of the sag of the conductor at 60°, initial stringing condition, in the ruling span selected. This loaded design tension should in no case exceed 50 percent of the ultimate strength of the wire. For example, if 3/8-inch high strength steel, 3/8-inch high strength Copperweld, or 101,800 C.M. H.S. ACSR strand is used for a ground wire over 3/0 ACSR with a 600-foot ruling span, the initial sag of the ACSR in a 600-foot span is 11.7 feet. The initial sag of the ground wire for the same span should be .8 of 11.7, or 9.4 feet. When sagged this amount, the loaded tension that would develop in the three ground wires mentioned above will vary between 3,700 and 3,800 pounds or approximately 32.3 to 38.5 percent of the ultimate strength of the respective cables.

Clearances for Transmission Line Conductors from Supporting Structures

When transmission conductors are supported by suspension insulators, whether on tangent structures or on line-angle structures, the insulator string is free to swing about its point of support. The clearance from conductors to parts of the supporting structure will, therefore, vary with different conditions of conductor tension, temperature, wind loading, and horizontal and vertical spans supported by the structure, since these factors affect the angle through which the insulator string will swing.

It is necessary that limitations for clearances from conductors to the supporting structure be established for the different transmission voltages. Two sets of clearances have been adopted, one to insure adequate clearance under normal operating conditions, which are most likely to exist for prolonged periods of time, and the other for the worst operating conditions, which exist infrequently and momentarily. The first set of clearances are referred to as "normal" clearances and should be maintained under a condition of no wind on the conductor with conductor tension at 60° final. The second set of clearances are referred to as "minimum" clearances and must be maintained under conditions that will cause the conductor to swing closest to the supporting structure. This condition, for structures with crossarms for supporting the insulators, is at the lowest assumed temperature, no ice, and a four-pound transverse wind. For line-angle structures, where the insulator strings are attached to the pole, the condition for minimum clearance is at 120° final, with a four-pound wind blowing against the line angle.

With due consideration to the flashover characteristics of insulators and air gaps, and to the probability of surges under momentary swing conditions, the following clearances from supporting structures have been established as the normal and minimum clearances to be maintained:

Usual Line	Normal Clearance		Minimum Clearance	
Voltage	To Wood	To Ground	To Wood	To Ground
34.5 kv	1' - 7"	2' - 0"	1' - 0"	1' - 2"
46 kv	1' - 7"	2' - 0"	1' - 0"	1' - 2"
69 kv	2' - 1"	2' - 6"	1' - 3"	1' - 6"
115 kv	3' - 6"	4' - 0"	2' - 2"	2' - 8"
132 kv	4' - 6"	5' - 0"	2' - 9"	3' - 3"

Because of the variable factors mentioned above, no definite line angle limitations can be established for standard transmission structures. For post-type and pin-type structures, the maximum line angle is usually governed by the maximum allowable transverse load on the insulators (See Section 4). For suspension-type structures, the maximum line angle is usually governed by the permissible arc through which the insulators may be allowed to swing before conductor clearance to the structure

becomes too small. The line angle limitations for each type of structure should be determined for each line on the basis of normal level ground spans, however, and tabulated as shown on drawing TM-6. Such a drawing should be prepared as a guide to assist the engineer when spotting structures on the plan and profile. Where an actual line angle is near the dividing angle between two types of structures, and where the horizontal and vertical spans are different from those assumed in preparing the guide, the angles of insulator swing must be computed to insure that the proper structure is used. The permissible angles of insulator swing for the various standard REA structures are listed below:

Type Structure	Number Insulators	Maximum	Normal	Minimum
46 - 34.5 kv	-	-	-	-
TS-3	4	*	14°	-1°
TS-4	4	*	34.5°	23°
TH-1	3	66° 30'	48° 40'	*
69 kv	-	-	-	-
TS-1 (8' arm)	4	45°	21° 25'	*
TS-1 (10' arm)	4	54° 30'	35°	*
TS-1-B (10' arm)	4	74°	50° 30'	*
TS-3	5	*	19° 30'	+ 3°
TS-4	5	*	39° 30'	23°
TH-1	4	64° 30'	41° 30'	*

* No Limitation.

The maximum angle of swing is the greatest angle with the vertical through which the insulator string may be allowed to swing under conditions for minimum clearance. When insulator strings are attached to the pole, as on structure TS-4, there is no limitation on maximum swing.

The normal angle of swing is the angle through which the insulator string will swing with no wind and with conductor tension at 60°, final. When insulators are attached to crossarms, as on structure TS-1 the normal angle of swing must not exceed the allowable normal angle of swing. When insulators are attached to the pole, the normal angle of swing must not be less than the allowable normal angle of swing.

The minimum angle of swing, when insulators are attached to the pole, is the least angle, under conditions of minimum clearance, through which the insulator string must swing. When insulators are supported from crossarms there is generally no limitation on minimum swing.

The following formulas should be used for computing the angles of insulator swing for structures on line angles:

1. For maximum angle of swing:

$$\tan \phi = \frac{(2)\ (To)\ (\sin \tfrac{1}{2}\theta) + (H)\ (Wh)}{(V)\ (Wv) + (\tfrac{1}{2})\ (Wi)}$$

2. For normal angle of swing:

$$\tan \phi = \frac{(2)\ (T60)\ (\sin \tfrac{1}{2}\theta)}{(V)\ (Wv) + (\tfrac{1}{2})\ (Wi)}$$

3. For minimum angle of swing:

$$\tan \phi = \frac{(2)\ (T120)\ (\sin \tfrac{1}{2}\theta) - (H)\ (Wh)}{(V)\ (Wv) + (\tfrac{1}{2})\ (Wi)}$$

The symbols in the above formulas represent the following:

ϕ - Angle with the vertical through which the insulator string swings.

θ - Line angle

To - Conductor tension at lowest assumed temperature, initial.

T60 - Conductor tension at 60°, Final.

T120 - Conductor tension at 120°, Final.

H - Horizontal span, which is $\frac{1}{2}$ the sum of adjacent spans.

V - Vertical span, which is the distance between the low point of sag in adjacent spans.

Wh - Wind load per foot of a four-pound wind on the bare conductor.

Wv - Weight per foot of bare conductor.

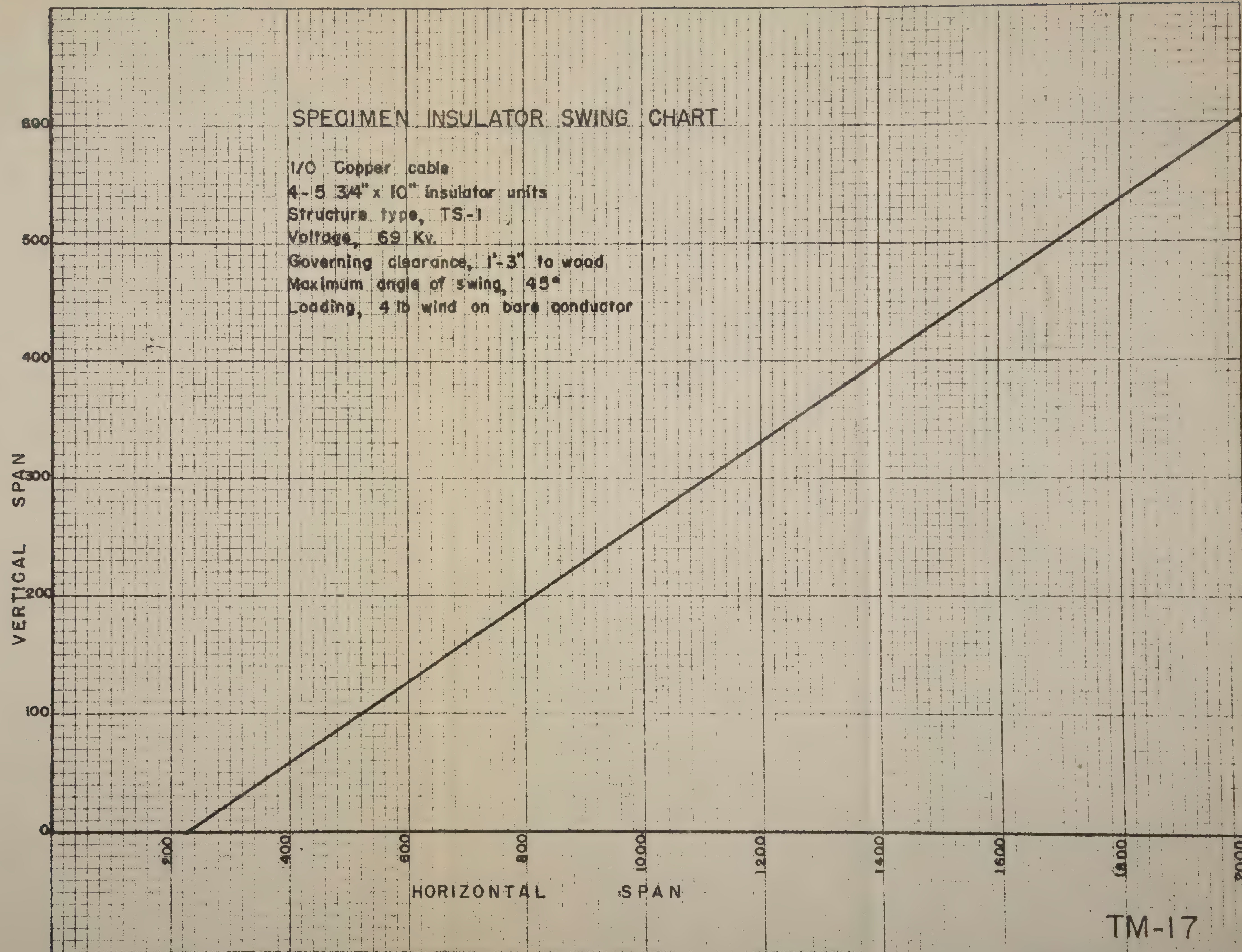
Wi - Weight of insulator string.

For tangent structures with suspension insulators, the normal and minimum angles of swing have no significance, and the formula for the maximum angle of insulator swing becomes:

$$\tan \phi = \frac{(H)\ (Wh)}{(V)\ (Wv) + \tfrac{1}{2}\ (Wi)}$$

To avoid frequent computations while structures are being spotted on the plan and profile a line representing the tangent of the maximum allowable angle of swing may be plotted on a sheet of graph paper with the vertical span represented by the vertical axis, and the horizontal span represented by the horizontal axis. Since the maximum allowable angle of insulator swing is fixed, values for plotting the line may be computed by assuming values of horizontal spans and solving for the corresponding vertical spans. When a chart is thus plotted, no further computations are necessary. To check the swing on a given tangent structure, the point corresponding to the horizontal and

vertical spans supported by that structure should be plotted on the chart. If the point lies above the line on the chart, it indicates that the vertical span supported is great enough to prevent excessive insulator swing. If the point lies below the line it indicates that insulator swing will be excessive, and the structure arrangement is not satisfactory. Drawing TM-17 is a specimen of such a chart.


SPECIMEN INSULATOR SWING CHART
1/0 Copper cable
4-5 3/4" x 10" insulator units
Structure type, TS-1
Voltage, 69 Kv.
Governing clearance, 1'-3" to wood
Maximum angle of swing, 45°
Loading, 4 lb wind on bare conductor
VERTICAL SPAN
600
500
400
300
200
100
0
HORIZONTAL SPAN
200
400
600
800
1000
1200
1400
1600
1800
2000
TM-17

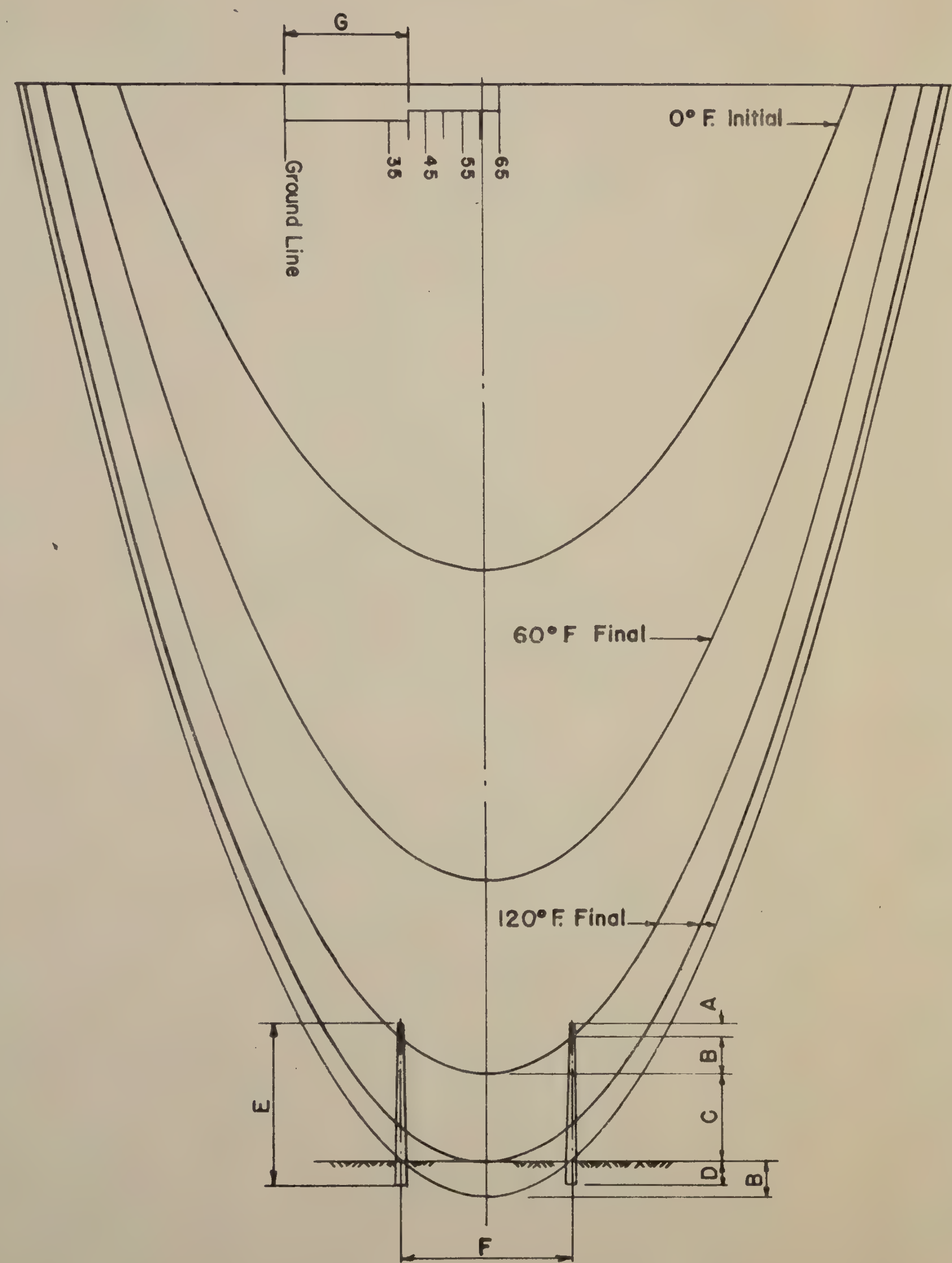
SECTION 8

Preparation of Sag Template

The sag template used for spotting transmission structures should be made of a transparent celluloid or plastic material approximately .03 inch in thickness. To obtain values for plotting sag curves, the sag values for the ruling span should be extended for spans both shorter and longer than the ruling span. It is sufficiently accurate to do this by computing the sag as proportional to the square of the spans, in accordance with the formula for the parabola. For ease in computing and plotting, sag values for even span lengths of 200 feet, 400 feet, 600 feet, 800 feet, etc., should be determined. The template should be made to include spans three or four times as long as the normal level ground span, to allow for spotting structures on steep hillsides. Sag values for plotting curves for conditions of 120° final, 60° final, and at the lowest assumed temperature, initial, must be computed. The low temperature initial, and the 60° final curves are used for determining the effective vertical spans supported by individual structures under these conditions, and the 120° final curves are used for determining ground clearance. The template should be cut to allow one foot greater clearance than given in table on page 4 as recommended in Section 2, to permit minor shifts in structure location.

The relation between the 120° final curves on the template is clearly shown on drawing TM-7. The low temperature and 60° curves may be placed in any convenient location on the template. A sag template drawing, similar to drawing TM-7, should be prepared for each line as a guide for cutting the template. A new template must be prepared for each line where there is any variation in conductor size, conductor configuration, assumed loading condition, design tension, ruling span, or voltage, as a change in any one of these factors will change the characteristics of the template.

To construct the template, the curves should first be plotted on a piece of regular profile paper to a scale of 400 feet to the inch horizontally, and 40 feet to the inch, vertically. The transparent template material should then be placed over the sheet and fastened securely with drafting tape. With a sharp pointed steel scriber, the centerline should be etched lightly, and the outside edges of the template etched deeply so that the template can be easily broken out. The template material should then be detached from the paper and the edges broken off and sanded smooth before the remaining curves are etched in. A guage should also be etched at the top of the template for ready measurement of the height above ground of the lowest conductor for various heights of poles. The etched grooves should be filled with ink to make them easier to see when the template is used.



2/0 ACSR Heavy Loading 600' Ruling Span Design Tension- 2645#- 1/2" Ice, 4 Lb. Wind at 0° F Reference Charts - Alcoa No. 8-996 & 8-997				1/0 F CWC Heavy Loading 600' Ruling Span D.T.-3268# 1/2" Ice, 4# Wind at 0°F CWEA charts OF7-H50F & N		
SPAN feet	SAG - feet			SAG - feet		
	0°F. Initial 640 Lbs.	60°F. Final 475 Lbs.	120°F. Final 450 Lbs.	0°F Initial 1420 Lbs.	60°F Final 1080 Lbs.	120° F Fin. 950 Lbs.
200	1.5	1.9	2.1	1.3	1.6	1.9
400	5.8	7.7	8.2	5	6.6	7.6
600	13.1	17.4	18.5	11.2	14.8	17
800	23.3	30.9	32.9	20	26.3	30.5
1000	36.4	48.3	51.4	31.2	41.2	47.5
1200	52.4	69.6	74.0	45	59.5	68.5
1400	71.3	94.7	100.7	61	81	93
1600	93.2	123.7	131.6	80	106	121
1800	117.9	156.6	166.5	101	134	153
2000	145.6	193.3	205.6	125	165	190
2200	176.1	233.9	248.7	151	200	230
2400	209.6	278.4	296.0	180	238	275
2600	246.0	326.7	347.4	201	280	320
2800	285.3	378.9	402.9	245	325	370
3000	327.5	435.0	462.5	280	370	425

A - Dimension from top of pole to point of attachment of lowest conductor.

B - Sag in level ground span.

C - Ground Clearance. (From table, page 5 plus one foot)

D - Setting depth of pole.

E - Pole height

F - Level ground span

G - Dimension from ground to point of attachment of lowest conductor.

SPECIMEN SAG TEMPLATE

CWC & ACSR-HEAVY LOADING- 600' RULING SPAN

Scale:		Date:
H- 1"=400' V- 1"= 40'		TM-7

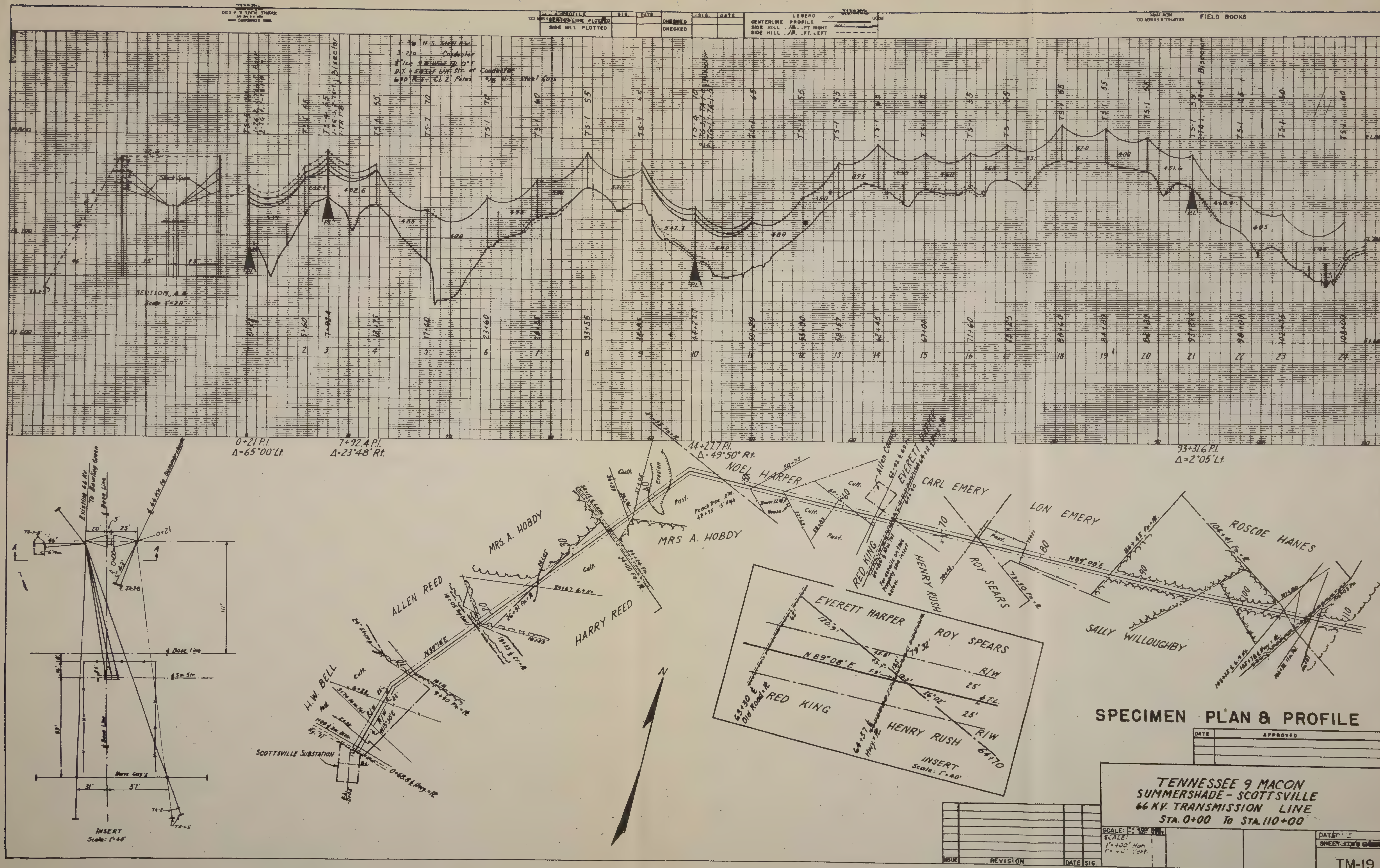
Preparation of Plan and Profile Sheets

The primary purposes of the transmission line plan and profile drawings are to insure correct design and economical construction. The final plan and profile drawings, in addition to being key construction drawings, are valuable as permanent records of property and right-of-way. Accurate collection of field data and translation of such data to plan and profile drawings are of utmost importance. Errors in this work will defeat the purposes of the drawings and nullify the accuracy of structure spotting with a template.

Field notes must include complete information necessary for plotting the profile and drawing the plan including such features as required by the Engineering Service Contract, REA Form DS-199. The necessity for taking data for plotting sidehill profiles where the ground slopes across the line of survey must not be overlooked. The sidehill profile should be a distance of approximately 10 feet beyond the outside conductor position.

Plan and profile sheets should be prepared to a scale of 400 feet to the inch horizontally and 40 feet to the inch vertically. On this scale, each sheet of plan and profile can conveniently accomodate 2 miles of line with 1,000 feet of overlap to tie the spotting into adjacent sheets. Where necessary for clarification of any portion of the line, such as the arrangement of lines adjacent to substations, inserts on a larger scale should be made on the plan and profile sheet. Drawing TM-19 is a reduced size copy of a typical plan and profile sheet. Drawings TM-14, 15 and 16 show recommended symbols, lettering sizes, and techniques.

Completed tracings of plan and profile sheets should be turned over to the system for filing as a permanent record. Drawings prepared in ink on tracing cloth will provide better permanent records. Whether prepared on cloth or paper, no attempt should be made to spot structures on the tracings. Spotting should be done on black and white prints and transferred to the tracings when completed. Structure spotting should not be inked in on the plan and profile until REA approval has been received and until all right-of-way commitments have been obtained and the line is ready for release for construction.



SPECIMEN PLAN & PROFILE
TENNESSEE 9 MACON
SUMMERSHADE - SCOTTSVILLE
66 KV. TRANSMISSION LINE
STA. 0+00 To STA. 110+00
TM-19
FIELD BOOKS
CENTERLINE PROFILE
SIDE HILL PLOTTED
CHECKED
SECTION A-A
INSERT
Scale: 1"=40'
0+21 P.I.
Δ=65°00'Lt.
7+92.4 P.I.
Δ=23°48' Rt.
44+27.7 P.I.
Δ=49°50" Rt.
93+31.6 P.I.
Δ=2°05'Lt.
H.W. BELL
ALLEN REED
HARRY REED
MRS. A. HOBBY
MRS A. HOBBY
NOEL HARPER
EVERETT HARPER
CARL EMERY
LON EMERY
ROSCOE HANES
RED KING
HENRY RUSH
ROY SEARS
ROY SPEARS
SALLY WILLOUGHBY
SCOTTSVILLE SUBSTATION
N39°16'E
N89°08'E
R/W
25'
63+30 ℄ Old Road
64+57 ℄ Hwy.
64+70
N
REVISION
ISSUE
DATE
SIG.
APPROVED
SCALE:
1"=400' Hor.
1"=40' Vert.

PLAN

℄ Transmission Line

Property Lines

R/ W Lines

State Lines

County Lines

Township, Range, and District Lines

Section Lines

1/4 Section Lines

Main Roads — 20' Gravel

Local Roads — 8' Dirt

Railroads

Fences (All kinds)

Existing O. H. Power Line (Ownership & Voltage) — OPS 66 KV.

Smaller Streams

Creeks

Rivers

Ponds

Wooded Section
(Where trimming is necessary)

Orchard

Marsh

Depression

Buildings (State kind) — Barn

PROFILE

Center Line

Side Hill, right

Side Hill, left

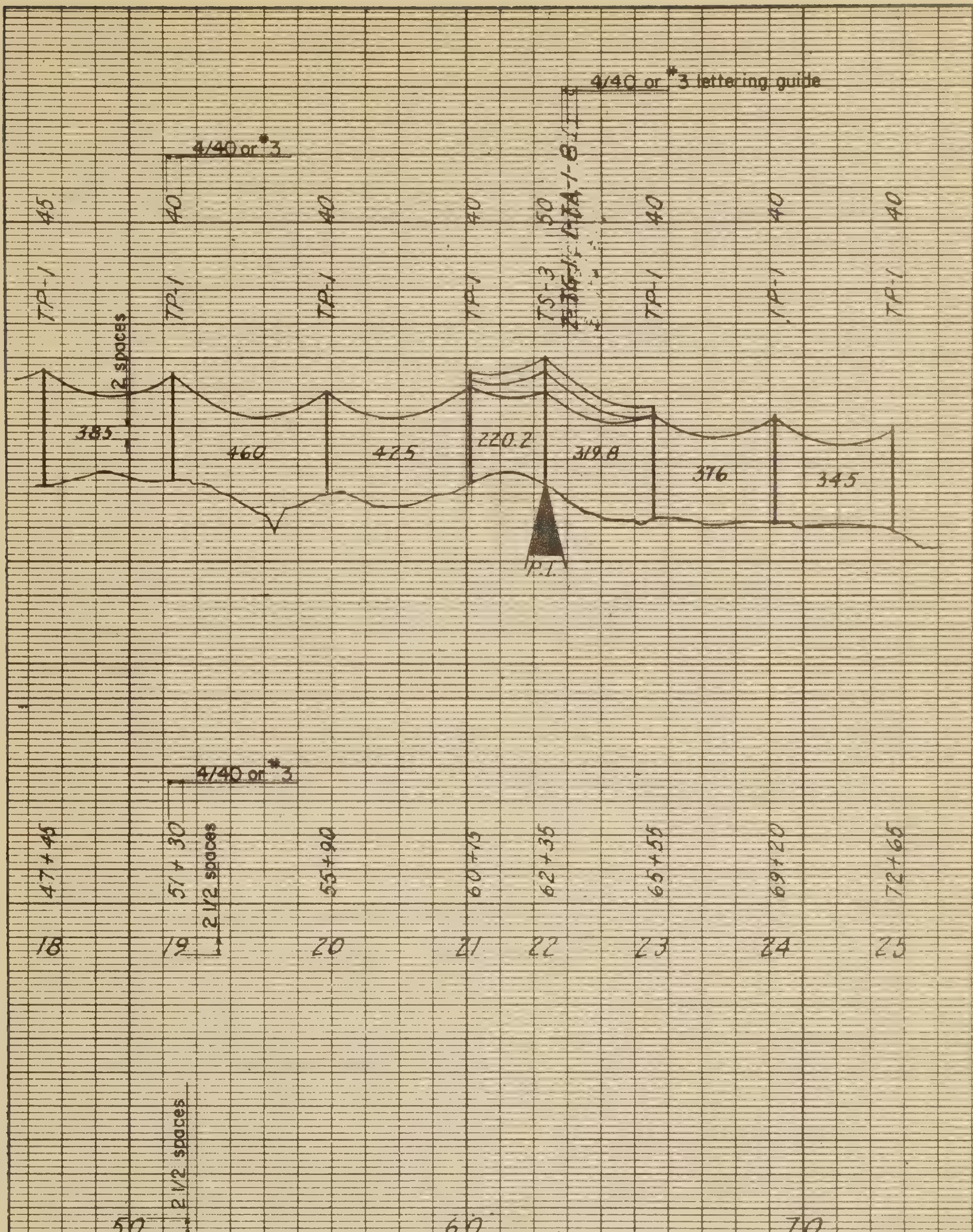
P. I.

NOTE:

For Vicinity Maps use same symbols as shown in Standard Style Sheet attached to form ADM-49, Standards for REA mapping.

TRANSMISSION LINE CONVENTIONAL SYMBOLS
FOR PLAN & PROFILE MAPS

Scale:		Date:
		TM-14



TRANSMISSION LINE

GENERAL PROFILE STANDARDS FOR WOOD POLE LINES

Scale:		Date:
		TM-15

2 1/2 Stationing and lettering on all general topography, No. 2½ Guide

3 Miscellaneous notes, distances on property lines, etc., No. 3 Guide

4 Property owners whose land does not touch Right of Way, No. 4 Guide

4 EACH 10TH STATION, STATIONING AND ANGLES ON P.I. POINTS AND PROPERTY LINES; TRACT NUMBERS, ETC., NO. 4 GUIDE

5 NAMES OF PROPERTY OWNERS, TITLES, CIVIL DISTRICTS, TOWNSHIPS, RANGES AND LAND LOTS, NO. 5 GUIDE

6 STATES AND COUNTIES, NO. 6 GUIDE

NOTE: Dimensions refer to 32nds. of an inch.

TRANSMISSION LINE STANDARD LETTERING FOR PLAN & PROFILE MAPS		
Scale:		Date:
		TM-16

Spotting Transmission Line Structures on the Plan and Profile Sheets

By use of plan and profile sheets the structure heights, locations, and types can be spotted so that construction will conform closely within the design requirements. Before spotting of structures is attempted, the span length limitations outlined on the design data summary sheet, Form DS-212R, must be computed, and a drawing similar to drawing TM-6 showing the arrangement of guys and the design data summary, should be prepared. The importance of this drawing must not be underestimated, for it provides the engineer spotting structures on the plan and profile, with a summary of information which he must have for selecting guys, anchors, and structure types to be used under various conditions. It is suggested that a sharp-pointed hard lead pencil be used for spotting to insure a greater degree of accuracy in the final results.

When a template, cut in the matter described in Section 8, is held vertically, and the clearance curve (the first curve from the edge of the template) is held tangent to the profile, the edge of the template will intersect the profile at points where structures of the basic height should be set. This relation is illustrated for a level span on the drawing TM-7 (see Section 8), but holds true regardless of the type of terrain. The second curve from the edge of the template represents the actual position of the conductor. To begin spotting structures, the template must be held vertically and the conductor curve must be held on the fixed point of attachment of the conductor to the take-off structure. The template should then be shifted so that the clearance curve barely touches tangent to the profile, and the point where the edge of the template intersects the profile determines the location of the next structure of basic height. This point may be marked by drawing an arc along the edge of the template where it intersects the profile. The template should then be shifted and adjusted to that with the opposite edge of the template held on the point previously located, the clearance curve will again barely touch the profile. As before, an arc should be drawn to mark the location of the next structure of basic height, and the process repeated to establish the location of each structure. After all structures are thus located, the structures and lowest conductor should be drawn in.

The above procedure can be followed exactly only on lines that are approximately straight and which cross relatively flat terrain without crossing roads, telephone lines, etc. When line angles, broken terrain, and crossings are encountered, it may be necessary to cut and try several different arrangements of structure heights and locations to determine the arrangement that is most satisfactory. For determining the height and location of structures of greater or lesser height than the basic structure, the template should be adjusted to provide the necessary clearance and an arc drawn along the edge of the template, even though the arc may not intersect the profile. At any given point along this arc, the vertical distance from the profile to the arc will

be the difference in actual pole height required and the basic pole height for a structure in that particular location. For example, if the basic height pole is 50 feet, a 55-foot pole would be required where a point on the arc drawn along the edge of the template was 5 feet above the profile, and a 45-foot pole could be used where a point on the arc was 4 1/2 feet below the profile.

In addition to maintaining clearances, uplift must be avoided on pin-type lines and excessive insulator swing must be avoided on suspension insulators. On pin-type lines, there is no danger of uplift if the low temperature initial curve does not pass above the point of conductor support on a given structure when the curve intersects the point of conductor support on the two adjacent structures. It is more difficult to avoid the possibility of excessive insulator swing because of wind load on lines with suspension insulators, as the uplift condition must not even be closely approached. The methods for computing insulator swing are discussed in Section 7. In some instances, on steep inclined spans, when the vertical span (the distance between the low point of sag in adjacent spans) is checked with the template, it may be found that the low point of sag will fall beyond the lower support. This indicates that the conductor in the uphill span exerts an upward pull on the lower support, the amount of which is equal to the weight of the conductor from the lower support to the low point of sag. This condition will not, therefore, alter the definition of the vertical span supported as being the distance between the low point of sag in adjacent spans.

Care must be exercised in broken country to see that the maximum allowable vertical span (limited by the strength of the crossarm) is not exceeded. For maximum accuracy, the vertical span for this purpose should be determined with a curve made for the sag under ice loads at 32°. For most conductors, however, the 120° final sag curve will closely approximate the curve for the ice-loaded conductor, and it may ordinarily be used when checking for maximum vertical span.

Successive plan and profile sheets should overlap 1,000 feet. The last structure on a sheet should be shown as a broken line on the following sheet to be used as a starting point.

As structures are located on the profile, the positions of the structures on the plan should be examined, to insure that the locations are satisfactory. The highest degree of accuracy in the preparation of the plan and profile, however, will not always show sufficient detail to indicate that all structure locations are satisfactory. For this reason, the template is cut, as described in Section 2, to allow one foot greater clearance than actually required in order to provide flexibility for minor shifts in structure location, if necessary, when structures are staked. If any structure location is changed when the line is staked, the plan and profile must be corrected to show the actual location.

Any special notes or sketches necessary to guide the construction crews should be inserted on the plan and profile. The first sheet of the plan and profile should also indicate the conductor size, loading, design tension, and ruling span for the line. It is not necessary to show this information on other sheets except where some change is made in the basic design.

Form DS-212R
(11-49)

TRANSMISSION LINE DESIGN DATA SUMMARY

All transmission lines must be designed for grade B construction or better. The following data and limitations must be prepared before structures can be spotted on the plan and profile and should be submitted with preliminary plans and specifications:

Project Designation_________________________ Date_______________

Line Location_________________________ Operating Voltage_____________

1. Loading condition:__________ inches ice:________pounds wind at________°F

2. Conductor: type______________; __________pounds design tension. (50% of ultimate recommended.)

Ruling span:________________

	Initial		Final	
Temperature	Lowest assumed ___°	60°	60°	120°
Tension				
Sag				

(Show sag and tension values for ruling span indicated. Refer to sag and tension charts used, if any.)

3. Overhead ground wire: type__________; ________pounds design tension. (Recommend stringing to 80% of conductor sag at 60°, initial.)

Ruling span:________________

	Stringing Tensions and Sags (Initial)				
Temperature	Lowest assumed ___°	30°	60°	90°	120°
Tension					
Sag					

(Show sag and tension values for ruling span indicated. Refer to sag and tension charts used, if any.)

4. Structural stress values:
   a. Crossarms: ______________pounds per square inch. (Recommend 25% of ultimate stress in bending, computed by taking moments about through-bolt without benefit of crossarm brace.)
   b. Poles: kind_______________; ___________pounds per sqare inch.

5. Maximum working loads for anchors and guys:

5' log	8' log	3/4" anchor rod	Type__________ guy strand_______
8000 lbs.	16000 lbs.	8000 lbs.	___________lbs.

6. Span length limitations:
   a. Ground clearance with 120° final curve ______________feet.
   b. Basic pole: height___________feet, class _____________
   c. Normal span on level ground ______________feet.
   d. Maximum horizontal span limited by conductor separation ______feet.

e. Maximum sum of adjacent spans limited by pole strength________feet
f. Maximum sum of adjacent spans with side guys ______________feet
g. Maximum vertical span limited by strength of cross arm________feet

7. Allowable angles of swing for insulator strings:

Type Structure	No. Insulators	Maximum	Normal	Minimum
34.5 KV				
TS-3	3	*	16°	-2°
TS-4	3	*	41°	25°
46 KV				
TS-3	4	*	14°	-1°
TS-4	4	*	34.5°	23°
TH-1	3	66°30'	48°40'	*
69 KV				
TS-1 (8'arm)	4	45°	21°25'	*
TS-1 (10' arm)	4	54°30'	35'	*
TS-1-B (10'arm)	4	74°	50°30'	*
TS-3G	5	*	19°30'	∤ 3°
TS-4G	5	*	39°30'	23°
TH-1G	4	64°30'	41°30'	*
TH-1BG	4	88°	67°30'	*

*No limitation.

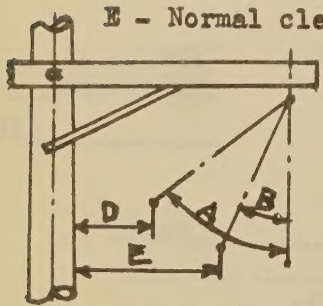
The above values are based on the following conductor clearances to the supporting structure:

Line Voltage	Normal (Clearance at 60° final, no wind)		**Minimum Clearance	
	To wood	To ground	To wood	To ground
34.5 KV	1' 7"	2' 0"	1' 0"	1' 2"
46 KV	1' 7"	2' 0"	1' 0"	1' 2"
69 KV	2' 1"	2' 6"	1' 3"	1' 6"

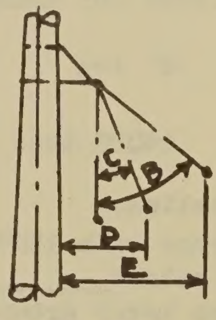
** For vertical angle structures use 4-pound wind at 120° Final.
For structures with cross arms use 4-pound wind at lowest assumed temperature, initial.

The maximum, normal and minimum angles of swing have the significance as shown on the sketches below:

A - Maximum allowable angle of swing.
B - Normal allowable angle of swing.
C - Minimum allowable angle of swing.
D - Minimum clearance.
E - Normal clearance.



CROSSARM STRUCTURE



ANGLE STRUCTURE

Angle "C" is plus if swing is away from pole, and minus if toward pole.